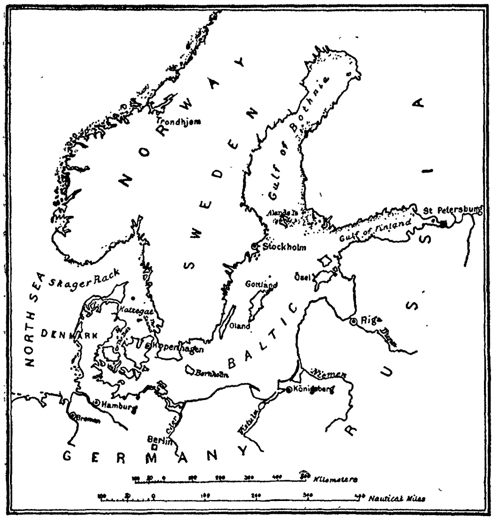
burden of upholding the high traditions of Great Britain in marine research and exploration on the shoulders of her scientific men. In their name I appeal to all our well-to-do fellow-countrymen in every walk of life for assistance, so that these new duties may be discharged in a manner worthy of the Empire and of the well-earned reputation of British Science.

JOHN MURRAY.

RECENT PROGRESS IN OCEANOGRAPHY.

UNDER the title 'On the Laws of Movement of Sea-Currents and Rivers,' Dr. A. W. Cronander, of the Technical School at Noorköping, Sweden, has recently published a volume, giving the results of researches based upon his observations of



currents at different depths, taken in 1875–1877 from the lightships in the Baltic, the Great Belt and the Sound. Similar observations on the rivers Göta Elf and Motala Ström in Sweden, in the years 1893–1895, are also utilized together with the regular daily observations of winds and surface currents, recorded on the lightships in the Baltic and in the passages leading thence to the North Sea.

These results are certainly very interesting as they establish the fact that the currents in the Baltic obey the winds and that none of the other causes, to which we are accustomed to attribute motions in sea water, such as differences in density and temperature, and affluence of rivers, produce any currents which are either distinctive or perceptible.

Under the assumption that Dr. Cronander's investigations are not readily accessible to many of those interested in these matters, I propose, with his approbation, to furnish a short résumé to this journal.

Dr. Cronander takes up the question of the existence of a current from the Baltic into the North Sea, on account of difference of level. This difference has been determined by precise leveling, between the Bothnian Gulf, near Sundwall, and Levanger, near the Frith of Trondhjem, and is 0.725 m. On account of the difference in specific gravity, which is assumed at 1.027 in the North Sea, and 1.003 in the Bothnian Sea, the difference of level has been calculated to be 0.546 m. This would give a fall of the Baltic current of 1 to more than 3,000,000, and since it has been demonstrated that with an inclination of 1 : 500,000 the motion of water is hardly perceptible, it is concluded that difference of level between the Baltic and North seas cannot produce any appreciable currents.

But it has been tacitly assumed that in consequence of the great quantities of fresh water which are constantly precipitated into the Baltic by some 250 rivers (among them five of the larger ones in Europe), there must exist a surface current, the so-called *Baltic Current*, by which this excess of water is carried off into the North Sea.

Dr. Cronander finds two alternate currents in the passages leading to the North Sea, which are controlled solely by the

winds. With easterly winds (N. N. E., to S. S. E.), the water flows into the North Sea through all these channels, and with westerly winds (N. N. W., to W. S. W.), the current reverses from the North Sea into the Baltic. The difference between the quantity of water which, within a specified time, is carried out of the Baltic and into it, indicates the quantity which has been definitely removed from the Baltic within the time, and furnishes an indication of the force of the Baltic current; hence the current has no specific existence but only a differential one.

Assuming t to be the time during a year when outgoing currents prevail, and v the mean velocity, likewise t' the length of time for inflowing currents during the period, and v' their mean velocity, the mean velocity of the Baltic current will be given by the formula

$$V = \frac{vt - v't'}{t + t'}.$$

Dr. Cronander has calculated this velocity for the sound for two decades, 1850–59 and 1864–73, and obtained for the first period $v = 1.204$, $v' = 1.304$ and $V = 0.257$ and for the second period $v = 1.153$, $v' = 1.230$ and $V = 0.210$ (velocities in knots per hour). It will be noticed that the mean current from the North Sea is stronger than that from the Baltic, and since, in spite of this, more water is conveyed from the Baltic than into it, the outgoing current must be of greater duration. Similar calculations have also been made for the Great Belt, but only for the term of a few years; they show that in some years more water flows through this passage *into* the Baltic than *out* of it. These measures of velocity apply to the surface only, and now the important question comes up, to what depth is the current propagated and what is the law of decrease with increasing depth?

Currents which are caused directly by the winds, denominated '*drift currents*,' show a very rapid decrease of velocity with increase of depth in consequence of friction, as indicated in the adjoining diagram (A); in rivers, where the velocity is due to the difference of level, the decrease of velocity with the depth is very gradual as shown by the accompanying diagram (B). The difference in the shape of these diagrams is so apparent that nobody can make a mistake in deciding whether a given current belongs to one or the other of the two classes.

Now Dr. Cronander found that wherever he measured the currents under the surface, whether in the Baltic, the Sound, the Belt, or the Cattegat, the observations always pointed to differences of level as the cause, and against a supposition of a direct effect of the winds. This is then another important conclusion which Dr. Cronander reached, viz.: that although the currents of the Baltic appear to obey the winds, the winds are not the immediate cause, but the difference of level created by preceding winds. To illustrate: Supposing a strong westerly wind to have been blowing over the Baltic, it will produce an accumulation of water in the eastern and northern part, and a corresponding depression of level in the western part. As soon as these westerly winds are replaced by easterly ones, the pent up waters will flow in an easterly direction, more in consequence of reaction against the preceding westerly winds, than in obedience to existing easterly winds. It must be observed that the greatest velocities were not generally found at the surface. Thus, in the Sound the average velocity of the outgoing current, 3.55 decimeters per second, was found at the surface; that of the ingoing current, 3.66 decimeters at the depth of 1 fathom. For the Great Belt, the corresponding figures were 3.81 decimeters at 4 fathoms for the outgoing, and 3.78 at 6 fathoms for the ingoing current. The shift of greatest velocity from a surface to a

lower plane is satisfactorily explained by the interference of local winds with the direction of the surface currents.

The existence of a heavier layer of salt water in the deeper part of the Baltic has been generally attributed to the existence of an undercurrent from the North Sea into the Baltic. Dr. Cronander found no traces of such an undercurrent in the shallow part of the Sound, where, at 5 fathoms depth, the ingoing and the outgoing currents each reached to the bottom. He compares the movement of the water here to that of two wedges, one of fresh water at the surface which has its base in the Baltic, and superposed upon one of salt water which has its base in the North Sea; both wedges are driven as a whole backward and forward by the currents, with the effect that sometimes the whole Sound is nearly filled with fresh water and at other times with salt water.

In the Great Belt the conditions were found to be somewhat different. With strong easterly or westerly winds, the outgoing or ingoing currents reach to the bottom, but sometimes the brackish water from the Baltic combines with the salt water from the North Sea in the shallow part of the Belt, and constitutes a homogeneous water-mass which is moved forward and backward. Again, sometimes a distinct bottom current is formed which moves in an opposite direction to the surface current. With low water in the Baltic, and an outgoing surface current, an ingoing bottom current may arise; and with high water in the Baltic, and ingoing surface current, an outgoing undercurrent may be called into existence.

From these statements we conclude that the assumed undercurrent from the North Sea into the Baltic does not present the normal condition, but that undercurrents into and out of the Baltic may occasionally be called into existence in the Great Belt by an effort of water at the bottom, to restore the hydrostatic equilibrium when it has been disturbed at the surface, and such a restoration at the surface is prevented by

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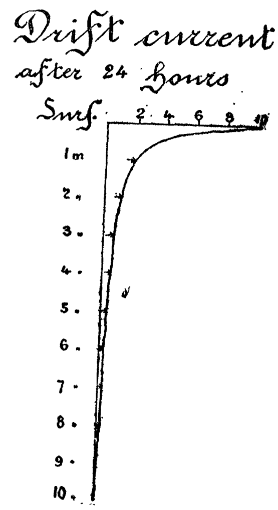

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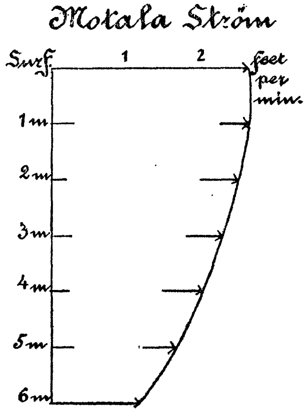

the winds. Hence, we may assume that the greater part of the salt water, which we find at the bottom of the Baltic, finds its way into it by surface currents, and that by reason of its weight and loss of heat by contact with the colder water, it settles to the bottom.

In the northern Baltic, two alternating sets of currents were found; an outgoing one, coming from a N. N. E. direction with

a mean velocity of 1.06 decimeters per second at the surface, and 0.20 decimeter at the bottom in 55 m. depth, and an ingoing current from S. W., to W. S. W. with 2.16 decimeters velocity at the surface and 0.37 decimeter at the bottom. With strong winds the currents extended all the way to the bottom; with feeble winds still water is found at the bottom. Contrary local winds often produce still water or drift currents at the surface, when the main current is outgoing, but the stronger inflowing current is seldom stopped by contrary winds.

The salt determinations in the northern Baltic show a surface layer of 15–20 m. deep with an average saltness of 5.6 to 5.7 grammes of salt to the liter; between 20 and 45 m. a mixed layer of 6 to 7.3 grammes; and between 45 and 55 m. a nearly homogeneous bottom layer of 7.5 to 7.7 grammes of salt, which shows scarcely any variation during different seasons. This bottom layer also shows but slight changes of temperature; between June 11 and August 16, 1877, the temperature rose from 0°.5 to 1°.6, while at the surface during the same time it rose from 4°.6 to 17°.5.

Thus far I have followed Dr. Cronander, but I feel tempted, before concluding, to make a few remarks concerning the conclusions reached, and also to apply the results obtained towards the explanation of some of the more prominent ocean currents, which he has refrained from doing.

In the estimate of the Baltic current, based on difference of level between the Baltic and North Sea, a uniform slope of 1: 3000000 from the head of the Baltic to the North Sea has been assumed. It appears quite probable to me that, on account of the obstruction which the narrow and shallow passages interpose to the free passage of water between these two seas, the surface of the Baltic will be nearly on a perfect level and that at its juncture with the North Sea there will be a much greater difference of level than that indicated by a slope of 1: 3000000 and quite sufficient to produce perceptible currents in the Sound and Great Belt. In a critical examination of the currents in these two passages, I think the tidal currents should have received some consideration. The rise of the tide in different parts of the Baltic furnishes the means of determining the strength of these currents; and, however small it may be, the figures should have been produced just as has been done with the so-called Baltic Current. Furthermore, I am willing to admit that Dr. Cronander's observations prove that in the open Baltic the currents move in obedience to laws identical with those governing the flow of rivers; but in the Sound and Great Belt the direction and flow of currents are so greatly modified by contraction of the channels, that a current, which in the open Baltic or North Sea might be considered a mere drift current, could be easily changed into a veritable river current.

The equatorial currents appear to me to be fair examples of surface currents which derive their strength solely from the action of the trade winds. Unfortunately, deep-sea current observations are not at hand, but, if the above supposition holds, their depth cannot be very great. The current through the Strait of Yucatan, which at the surface surpasses the strength of all the Gulf Stream waters, is assumed to be due to the partial barrier, namely, Yucatan and Cuba, between the Caribbean Sea and the Gulf of Mexico. According to Pillsbury's observations, I estimate its depth at 200 fathoms. The undercurrent from the Gulf of Mexico, which I am led to believe exists, from comparison of the quantities of water that enter the Gulf and leave it through the Strait of Florida, may possibly be explained upon the same grounds as those undercurrents occasionally met with in the Great Belt, viz., an effort towards the restoration of

equilibrium, disturbed at the surface by the effect of the winds. The conditions are nearly identical. In the Baltic, easterly winds and currents force the waters into the North Sea, raise the level of the Great Belt, and give rise to an undercurrent from the North Sea into the Baltic. Here we assume that the waters, which the equatorial currents succeed in piling up in the western part of the Caribbean Sea, seek a passage through the Yucatan Strait into the Gulf of Mexico; that in this passage the level stands higher than on either side, and that the water forced into the Gulf of Mexico raises its level over that of the eastern portion of the Caribbean Sea. Since equilibrium cannot be restored at the surface, it is done by an undercurrent from the Gulf. Somewhat different from these conditions are those which are supposed to govern the flow of the Gulf Stream from the Gulf of Mexico into the Atlantic. Pillsbury's current observations in the Strait of Florida show that in the narrow parts the current touches bottom. There remains little doubt at present that the Gulf Stream owes its origin to the difference of level between the Gulf of Mexico and the Atlantic. Recent precise leveling, by the Coast and Geodetic Survey, indicates that between the mean level of the ocean at St. Augustine, on the eastern coast of Florida, and that of the Gulf at Cedar Keys, on the western, there exists a difference of nine-tenths of a foot. Some surprise might be expressed that such an insignificant difference should be able to set such a powerful stream into motion. But if we assume the Gulf to represent a basin, and the Strait of Florida a narrow orifice by which it communicates with the Ocean and apply Torricelli's theorem, neglecting friction, we obtain the velocity of $v = \sqrt{2g \times 0.9} = 7.6$ feet per second, which is not very greatly in excess of the average velocity of the Gulf Stream in the most contracted portion of the Strait.

Some authors speak of the impulse of the Gulf Stream carrying its waters against the western coast of Europe, and producing a higher level there than exists on the eastern coast of North America. Whatever impulse the Gulf Stream possesses is due to its higher level, and I cannot comprehend how such an impulse can make it ascend an inclined plane. What is meant, I presume, is the Gulf Stream drift, the motive power of which is the prevailing westerly winds of the North Atlantic. It is generally supposed that this Gulf Stream drift is compensated for by an undercurrent setting from the western shores of Europe in a southwesterly direction.

A. LINDENKOHL.

OBSERVATIONS ON RHYTHMIC ACTION.

Two entirely different forms of regularly repeated action are to be distinguished. In one form the subject is left free to repeat the movement at any interval he may choose. This includes such activities as walking, running, rowing, beating time, and so on. A typical experiment is performed by taking the lever of a Marey tambour between thumb and index finger and moving the arm repeatedly up and down; the recording tambour writes on the drum the curve of movement. Another experiment consists in having the subject tap on a telegraph key or on a noiseless key and recording the time on the drum by sparks or markers. Other experiments may be made with an orchestra leader's baton having a contact at the extreme end, with a heel contact on a shoe, with dumb-bells in an electric circuit, and so on. For this form of action I have been able to devise no better name than 'free rhythmic action.'

In contrast with this there is what may be called 'regulated rhythmic action.' This is found in such activities as marching in time to drum-beats, dancing to music, playing in time to a metronome, and so on. A